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Digital Manufacturing and Design in the Aerospace Industry

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Our Approach

DManD conducts transdisciplinary research across the areas of design, materials, and manufacturing to accelerate the realization of new products with optimized and unprecedented behavior.



Digital Manufacturing & Design (DManD) Research Centre

DManD creates new technologies and integrates them in workflows to create and exploit digital threads through the design and manufacturing value chain to enable product innovation.







Overview

- Additive Manufacturing (aka 3D Printing)
- Multimaterial topology optimization
- 4D printing
- Digital design and manufacturing in the supply chain





AM Process Categories



Part Consolidation



Value of Direct Manufacturing

- Engineering Design:
 - Direct from 3-D Model Base Definition
 - Design and Build Flexibility
- Production:
 - Eliminate non-recurring tooling costs
 - Lower recurring unit part costs
 - Faster part delivery times
 - Supplier flexibility
 - Direct Fabrication:
 - 50% Cost Reduction
 - 67% Cycle Time Reduction at Minimum
- Product:
 - Reduced part count and weight
 - · Lower inventory and transportation costs
 - Improved Life Cycle Product Costs



Fuel Nozzle for GE LEAP Engine

- Cobalt-Chrome, Powder Bed Fusion (EOS DMLS)
- ~18-20 parts consolidated into 1
- 19 nozzles per engine
- 25% lighter, better performance
- 5X improvement in durability
- 5X fewer brazes and welds





GE Advanced Turboprop

- Turboprop for Cessna Denali
- GE claims it consolidated 845 parts into 11 using AM
- ~20% reduced fuel burn
- 10% more power
- Lower weight
- www.ge.com/additive







Products with Embedded Electronics

www.optomec.com/printed-electronics/aerosol-jet-core-applications/internet-of-things/



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Topology Optimization: Metal Commercial Examples



NextGen spaceframe, EDAG Engineering





Airbus, AutoDesk "Bionic Partition"



Large-Scale Topology Optimization



NASA Common Research Model, 27m long Aage, Andreassen, Lazarov, Sigmund, *Nature* Vol 550: 84–86 (05 October 2017)



Voxel-based Manufacturing Technology

- Stratasys Polyjet technology allows the deposition of photopolymer ink droplets at a resolution of 600 x 300 x 845 dpi.
- One cubic mm contains about 20,000 voxels.
- Either a stiff (Vero, E~2 GPa) or soft (Tango, E~1 MPa) can be jetted at each voxel.





Digital Design and Manufacturing Workflow





Prof. Martin Dunn, Sai-Kit Yeung, Sawako Kaijima



Design Automation









CASE STUDY - MULTISCALE MULTIMATERIAL TOPOLOGY OPTIMIZATION

Digital Fabrication







Optimal 3D Structures







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Complex Composite Parts



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4D Printing

3D Printing



Active Materials

(changes shape or properties in response to stimulus)







4D Printing Examples



Skylar Tibbits, MIT Architecture 2013



Kevin (Qi) Ge, SUTD





3D Printing Processes

Polyjet Technology Stratsys J750 3D Printer







Multimaterial PµSL Custom



Two-Photon PL Nanoscribe



Sequential Folding





GT, SUTD: Mao et al., 2015, *Scientific Reports*



Morphing Aircraft Wings



Airbus A320, a truly global programme





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Impact of Industry 4.0 on AM

- AM facilitates I4.0 implementations since can directly utilize all that integrated information in product models
 - No tooling required; faster, agile manufacturing
- Point-of-sale AM of customized products
 - Integrate supply chain
 - Distributed, customized products enabled
- Embedded sensors enable AM products to integrate into IIoT
- "Digital watermarking" to eliminate counterfeit parts
- Should significantly increase adoption of AM





Hearing Aids

• Custom manufacture at audiologist shop?

Lantos Technologies





3D Printing Supply Chains

- UPS has 3D printing main shipping center, 60+ stores, and Singapore (Fast Radius, SAP partners)
 - Same day delivery in some US locations (3D fax?)
 - 24 hour delivery of 3D printed parts in Asia from SG
- DHL investigating 3D printing
- Home Depot, Lowes home improvement stores

www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/dhl_trendreport_3dprinting.pdf





Digital Watermarks in Metal AM Parts



Crystallographic texture control achieved within AM deposited Inconel 718 through precise control of temperature gradient and liquid-solid interface velocity. R. Dehoff, Oak Ridge National Labs, USA



316L stainless steel Bar codes written into specimen Read by eddy current Niendorf et al., Rapid Prototyping Journal, 2016





Conclusions

- Additive Manufacturing is a type of digital manufacturing that will have a great impact on the aerospace industry
- Multimaterial topology optimization has applications to polymer, metal, and composite parts and structures
- 4D printing (active materials) has long-term potential to simplify designs and improve performance
- Digital design and manufacturing in the supply chain:
 - Distributed/local manufacturing
 - Print-on-demand
 - Digital watermarking to prevent counterfeit parts





DManD Contributors

Pls

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